TOOKER AND FORCE —TITANIUM



Planimetric Base from National Atlas 1:7 500 000, 1970

INTRODUCTION

The map shows a number of present and potential domestic sources of rutile (TiO2) and ilmenite (FeTiO₂), the two main types of titanium minerals that are the raw materials for titanium metal and TiO₂ pigments. Both minerals are used in pigment manufacture, but only rutile is presently used in metal manufacture. Strong refractory titanium metal is essential in the aircraft and space industries and for other structural products; TiO pigments are critical in paints, ceramics, paper, plastics, and other materials (Wessel, 1976). Substitutes such as aluminum and high-nickel steel for titanium metal and lead pigments for TiO2 are inferior, or the substitute is an equally critical material. Titanium scrap is extensively recycled, but pigment is dissipated in use and is not recoverable. Thus mining of new primary titanium minerals is required to supply the increasing amounts of these essential materials that are being consumed.

Geologically, titanium is a major constituent of the Earth's crust, but only a few titanium oxide minerals have economic value. The United States has resources of perovskite (CaTiO₃) and the TiO₂ minerals anatase and brookite, in addition to ilmenite, altered ilmenite, and rutile. In crystalline rocks, titanium deposits are present in the igneous rocks anorthosite and gabbro as ilmenite, or rarely rutile, in alkalic igneous rocks as rutile, anatase, brookite, and perovskite, in metamorphic rocks as ilmenite and rutile, and in hydrothermally altered rocks, especially disseminated copper porphyries as rutile. In sedimentary type deposits, titanium is present in beach sand concentrations of all ages (both as altered ilmenite and rutile), in glacial lake deltas, in stream deposits, and probably in other environments. More extensive descriptions of individual deposit types are in U.S.

The nation has a comfortable (geologically available) potential domestic supply of ilmenite, but not of rutile. Thus the United States seems to be dependent on foreign sources for much of its rutile supply, and imports large quantities (as much as 90 percent) from Australia and other nations (Lynd, 1978). For economic reasons the nation also imports ilmenite (43 percent), although it could be relatively self sufficient, if necessary. Partly processed titanium metal (sponge) and titanium-rich

The purpose of the province map is to show the location and magnitude of current domestic titanium deposits or occurrences, whether economic or subeconomic. Both ilmenite and rutile provinces shown on this map compilation were derived from the localities documented in published reports such as Rogers and Jaster (1962), Herz and Eilertsen (1968), Klemic and others (1973), and updated information from the files of the U.S. Geological Survey titanium commodity specialist. The rationale of maps in the atlas of some metal and nonmetal provinces, of which this map is a part, and some of the technical terms and geologic concepts used are discussed and defined in a companion background report by Tooker

DISTINGUISHING MAP FEATURES The province map and accompanying tables are intended to summarize current information about the location, size, and areal distribution of ilmenite and rutile deposits or occurrences, and where possible in the context of the geologic system and deposit type in which they were formed. A province, as broadly defined herein, is an area on the map that contains sporadic to closely populated groups and clustered groups of present or former titanium-producing deposits and reported occurrences,

which contain this metal in amounts substantially above its average value in the Earth's crust (oceanic crust, 8,100 ppm (parts per million); continental crust, 5,300 ppm, according to Klemic and others (1973)). Within a province titanium generally occurs in a distinctive geologic setting, although some overlap or mixed geologic host environments occur. No distinction as to economic or subeconomic character is implied in this definition of a province, but the map also shows the main current and past production sites within provinces. Where possible, province boundaries are drawn on the basis of geologic units (based on King and Beikman, 1974), and some provinces therefore may the basis of geologic units (based on king and between 1774), and some provinces therefore may consist of a number of detached outlying areas. A boundary may enclose a large titanium-bearing intrusive mafic rock complex, a sedimentary basin, or irregular exposures of a sedimentary rock formation in which titanium minerals are concentrated. Where more than one geologic environment is associated with titanium concentrations, overlapping subprovinces are shown. Lacking a common mappable feature, a more generalized province boundary may enclose a cluster of localities in an area.

There are also a number of isolated or detached localities shown on the map that cannot now be readily evaluated but which, nevertheless, should not be overlooked. Whether these represent a naturally sparse distribution of titanium minerals whose resource potential is minimal at best, or are information about the region is incomplete remains to be determined. The province map thus shows the clue to a valuable new source area that has gone unrecognized by areas of current and past production, in a few cases areas where we think future supplies of primary or byproduct titanium materials can be obtained, and finally those areas that require more detailed geologic investigation for resource assessment.

The ilmenite and rutile localities have been classified into large and small sizes on the map for purposes of comparison in the metal and nonmetal province atlas series (Tooker, 1979). A large titanium deposit was defined by Rogers and Jaster (1962) as having combined production and remaining minable minerals in excess of 1 million short tons (907,000 metric tons) TiO2; we also include presently subeconomic deposits that recent studies indicate may have the potential for producing equivalent amounts of titanium. This size is roughly equal to 2 million short tons (1.8 million metric tons) of ilmenite. For comparison (using the 1978 price for altered ilmenite), such a large deposit would be valued at more than \$100 million and approximately equal at a minimum to a two-year supply (at the 1978 level of demand) of ilmenite (based on data from U.S. Bur. Mines, 1979). No comparable values for rutile are shown because there are no large domestic deposits.

On atlas maps the large deposits have been subdivided into those that were active producers in 1975, the base year for this survey, and those which for several reasons were not active, on the basis of U.S. Geological Survey information and a world survey of major mines by Mining Magazine (1976). Type A are those large active (ilmenite and (or) ilmenite and byproduct rutile) mines that were in production in 1975. Type B includes large inactive mines or undeveloped occurrences--past producers that may contain large potential resources which were temporarily closed for economic reasons, former large deposits considered mined out by 1975, those in which any current production is very small (all shown by a large solid symbol), and large undeveloped (possibly subeconomic) localities considered to have production potential (large open symbol). The period 1975-1979 has seen several mines closed or nearly closed due to increased competition from foreign deposits and (or) depletion of minable minerals. The mines at Sanford Lake, N. Y., Folkston, Ga., Green Cave Spring, Fla., and one at Lakehurst, N. J., have become type B deposits in 1979.

Many small active or inactive deposits or occurrences of both ilmenite and (or) rutile are shown as type C. Their past, present, and possible productive capacities are known or believed to be less than 2 million short tons ilmenite, or equivalent rutile, or are unevaluated. Four types of titanium materials are shown (small solid symbols), including titaniferous magnetite (small open dot) which in the absence of contained ilmenite presently is technologically unsuited for consideration as a titanium metal resource.

TITANIUM PROVINCES Twenty-five province and four overlapping subprovince areas having known and untested resource possibilities are present locally in all of the main geologic regions of the conterminous United

States. Although the resources shown in these provinces are known to exist (are geologically available) they may be subeconomic at present and are not all economically available. As noted, domestic economic sources of rutile are limited, but there are a number of geologic possibilities for increasing this resource that warrant further study. Ilmenite is an abundant mineral in many provinces, but its future availability, particularly along the Coastal Plains, may be limited by economic and environmental factors. Domestic resources in which rutile is the primary material mined occur only in local concentrations in provinces 15, 17, and 23, and in a few isolated occurrences elsewhere. The byproduct possibilities for this mineral, probably have not been fully recognized. Ilmenite beach placers along the Atlantic and Gulf Coastal Plains contain rutile, which is being recovered in province 1, and the granitoid intrusive host rocks for disseminated (porphyry) copper deposits in the Cordilleran belt are known to contain rutile which, if recovered, could become a significant domestic byproduct source. Some of these deposits occur in subprovince 9a. Deposits of kyanite and related

minerals commonly contain rutile also, and rutile might be recovered as a byproduct from such deposits The main domestic source for ilmenite is in heavy mineral placers of raised beach deposits. Provinces 1 and 2 contain the four presently operating ilmenite mines, three in Florida, and one in New Jersey. This activity contrasts with that reported on the map for 1975. Older beach deposits may also contain resources of titanium minerals, such as those in Mesozoic sands of provinces 13 and 16 in the Cordilleran belt and Gulf Coastal Plain. One of the most serious economic/environmental problems for surface mining of these deposits is that the resource often lies in the path of urban expansion, and the lands increasingly are becoming unavailable for resource use.

Among a number of other surficial ilmenite localities are the residual concentrations formed by lateritic weathering, which produced host residual clay and saprolite soils. These deposits may be considered as potential byproduct resources where they occur in province 7 associated with subeconomic bauxite in Washington and Oregon, with high-aluminum clay deposits in province 10 in Idaho and Washington, with bauxite in Arkansas in subprovince 15a, and in the saprolites of province 19 in the southern Appalachian Mountains. Heavy mineral concentrates derived from glacial outwash, recently recognized as a possible new type source in New York, subprovince 3a, may contain substantial ilmenite resources. Stream placers are also potential sources of ilmenite, and possibly locally of rutile in provinces 8, 9, 11, 14, and 20. These placers were derived from the weathering of nearby crystalline source rocks. Sedimentary ilmenite occurs as a potential byproduct (with fluorine and uranium) of phosphate rock mining in the southeast Coastal Plain, province 23, in central Florida.

Ilmenite also occurs in hard-rock deposits, but only limited mining is presently done in upstate New York in province 3. Potential resource of this type occur in eight of the provinces shown. Provinces 3, 5, 8, 12, 14, and 17 are associated with anorthosite and gabbro intrusive rocks found mostly in Precambrian basement terranes. Highly metamorphosed rocks host small titanium sources in provinces 9 and 19. Perovskite resources at Iron Hill, Colo., in province 4 are considered to be large. The economic viability of mining perovskite has yet to be demonstrated. More careful exploration in the identified titanium provinces and systematic geologic studies in adjacent similar geologic terranes or those elsewhere undoubtedly will result in increasing the amount of minable titanium minerals and the number of large-size deposits. A significant conclusion of this summary is that both ilmenite and rutile could be recovered in much greater amount than at present, as

REFERENCES CITED Herz, Norman, and Eilertsen, N. A., 1968, Titanium, in Mineral resources of the Appalachian region:

U.S. Geological Survey Professional Paper 580, p. 437-443.

King, P. B., and Beikman, H. M., 1974, Geologic map of the United States: U.S. Geological Survey Map, Klemic, Harry, Marsh, S. P., and Cooper, Margaret, 1973, Titanium, in United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 653-665. Lynd, L. E., 1978, United States dependence on foreign sources of heavy mineral contrates: American Institute of Mining and Metallurgical Engineers, Preprint 78-H-366. Mining Magazine, 1976, International mining survey: v. 135, no. 3, p. 233-234. Rogers, C. L., and Jaster, M. C., 1962, Titanium in the United States, exclusive of Alaska and Hawaii: U.S. Geological Survey Mineral Investigations Resource Map MR-29, scale 1:3,168,000. Tooker, E. W., 1979, Background information to accompany the atlas of metal and nonmetal mineral provinces in the conterminous United States: U.S. Geological Survey Circular 792 (in press). U.S. Bureau of Mines, 1979, Mineral commodity summaries: p. 72-73, 132-133, and 170-171. U.S. Geological Survey, 1976, Geology and resources of titanium: U.S. Geological Survey Professional Wessel, F. W., 1976, Mineral facts and problems, 1975 ed.: U.S. Bureau of Mines Bulletin 667, p.

PRELIMINARY MAP OF TITANIUM PROVINCES IN THE CONTERMINOUS UNITED STATES

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Table 1.--Location, main types of deposits, preliminary estimates of resource potential and status of geologic resource

information of titanium provinces in the conterminous United States Preliminary Status of geologic resource information³ Geologic estimates of resource potential^{2,3} Adequate Insufficient State Florida, Georgia, and Coastal Plains South Carolina Adirondack Mtns Southwestern (Iron Hill) Northern shield Minnesota Coastline sands Washington, Oregon and California 7 Oregon and Washington Portland Arizona 9a Arizona and Utah Bingham and other porphyry II copper deposits West central Upper Cretaceous sand New Mexico, Arizona, Utah, Wyoming, Colorado and Montana Wichita Mountains Magnet Cove Bauxite province Cretaceous sand Roseland-Montpelier Kyanite deposits North Carolina, South Southern Appalachian Carolina, and Georgia Mountains North Carolina, South Monazite placer districts VI Carolina, and Georgia -- X X --21 North Carolina, South Shoreline sands and Florida Phosphate district Florida -- R R Harford Co. Maryland -- X X --24 North Carolina Coastal plains

¹Main geologic types of deposits (Rogers and Jaster, 1962) Lode and other bedrock deposits

I Seggregations, dikes, lenticular masses, and disseminations in gabbroic and anorthositic host rocks

II Disseminations, veins, and irregular masses in granitic and metamorphic rocks III Veins and irregular bodies in carbonatites and syenitic rocks

IV Disseminations in sedimentary phosphate rocks Placer and other surficial deposits

V Beach and raised beach concentrations VI Alluvial concentrations VII Ancient or fossil heavy mineral (alluvial or beach) accumulation

VIII Laterite, residual clay, and saprolite concentrations in weathered terranes IX Glacial outwash concentrations

²Ranges for resource estimates (Force and Lynd, written commun., 1979) High - >1 million metric tons TiO₂

Low - <1 million metric tons TiO₂ ³Main titanium mineral in resource X = Ilmenite, perovskite, etc. R = Rutile and its polymorphs

Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U.S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the U.S. Geological Survey, Branch of Distribution, 1200 Eads St., Arlington, VA 22202.

This report is preliminary and has not been edited or

and nomenclature.

reviewed for conformity with Geological Survey standards